MESUR Pathfinder Rocket Assisted Deceleration (RAD) System

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The primary objective of the Mars Environmental Survey (MESUR) Network mission is to establish a network of small science stations on the Martian surface. The MESUR Pathfinder mission will be a precursor to MESUR Network. Pathfinder is a single spacecraft and lander which serves as a technology demonstrator for Network, hence the name Pathfinder. A critical function, among several, that Pathfinder must develop and prove for Network is a simple, robust, and low cost entry, descent and landing (EDL) system,

This paper will focus on the dynamic stability analysis used to show that solid rockets can be used in an uncontrolled manner to decelerate the lander just prior to landing on the Martian surface. Consider that the EDL system consists of four main subsystems, namely: (1) the heat shield/aeroshell, (2) the parachute, (3) the solid rockets, and (4) the airbags. The aeroshell converts over 99% of the lander's kinetic energy into thermal energy as the lander package enters the Martian atmosphere. A parachute is deployed when the lander reaches an altitude of 8-9 km, which further slows the lander to a terminal velocity of approximately 60 m/see. At this point in the landing sequence the forward portion of the aeroshell is discarded, and the lander is deployed on an incremental bridle from the aeroshell aft section known as the back shell. When the lander is approximately 30 m above the surface solid rockets are fired in the back shell to decelerate the lander to near zero vertical velocity. At this same instant airbags are inflated around the lander to further isolate the lander and its contents from the landing shock.

Dynamic analysis of the two body system consisting of the lander and back shell is needed to show that this system will be stable from when the solid rockets are fired until the bridle connecting the lander and back shell is severed. Due to the arrangement of the rockets in the back shell, as well as typical manufacturing imperfection of the rockets, thrust imbalances can be produced between the individual rockets which can cause the back shell to rotate about its center of mass and the lander center of mass. It is this stability problem that this paper focuses on. The problem is first formulated as a planar analysis. The lander and back shell kinematics are developed, and the dynamic equations are derived in closed form from a Lagrangian analysis. These equations are then exercised via simulation in order to evaluate the system stability in light of solid rocket timing mismatches, and thrust imbalance. The problem is the reformulated using the DADS dynamic simulation package to model the full three dimensional behavior of this system.